# COMMUNITY COMPOSITION AND SEASONAL VARIATION OF SOIL MITES IN AN APPLE ORCHARD IN BEIJING, CHINA

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**Abstract.** As one of the most abundant arthropod groups in soil, mites play an important role in the soil food web. Considering the lack of knowledge about temporal patterns of agricultural soil mite communities, we focused on the seasonal dynamics of soil mite communities (taxonomic and functional) in an apple orchard in the suburb of Beijing City, China. With sampling once per month for one year, a total of 7238 mites representing 45 species were collected. The top five most abundant species, *Scheloribates latipes*, *Oribatula truncate*, *Ramusella sengbuschi*, *Scheloribates fimbriatus javensis*, and *Tectoribates mahunkai* represented 83.5% of the total abundance of adult mites. The abundance, species richness and Shannon index of mites were similar among the four seasons. The soil abiotic factors (temperature and pH) had a significant relationship with some mite groups according to Pearson correlation analysis. Rao's quadratic entropy index (RaoQ), functional evenness index (FEve) and body size of oribatid mites were used to show the community function dynamics among temporal scales. We found that FEve and functional traits of oribatid mites were significantly different among four seasons. These results provide a good reference to understand the seasonal changes of soil mite communities and soil food web functions in orchards.

**Keywords:** *temporal patterns, agriculture, soil mites, taxonomy, function*

## Introduction

Soil biotas play an important role in agriculture, contributing to soil ecosystem stability and function (Mulder et al., 2011; Abbas and Parwez, 2020). They can significantly affect the quality of crops through food web interaction (Cao et al., 2011; Jiao et al., 2018). Although agriculture soil biodiversity in different groups has been studied to some extent, such as bacteria (Ramakrishna et al., 2020; Cao et al., 2022), nematode (van Diepeningen et al., 2006; Li et al., 2020) and mites (Behan-Pelletier, 2003; Jaksova et al., 2020; Ghosh, 2020), soil biota community temporal dynamic patterns remain enigmatic. Consequently, it is necessary to study the temporal dynamics of soil fauna in order to increase our understanding of agricultural soil fauna.

Mites (Acari) are among the most abundant soil arthropod groups and occupy multiple trophic levels of the soil food web (Maraun et al., 2023). Due to their sensitivity to soil environment changes, the diversity and numbers of soil mites could be regarded as ecological indicators for assessing disturbances in ecosystems (Amani et al., 2020). Because of the importance of mites in the soil food web and soil environment indication, the soil mite community has been demonstrated by various workers (Xu et al., 2012; Kamczyc et al., 2022). Despite these workers reported that the mite community experienced enormous fluctuations and was susceptible to the climatic factors, little is known about the seasonal changes of mite community in orchards.

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Functional diversity as an integral part of biodiversity is receiving considerable academic attention and is considered important in solving ecological problems (Petchey and Gaston, 2006). Although there is more and more evidence of how functional diversity impacts ecosystem processes (Mokany et al., 2008), some of the glaring knowledge gaps related to functional traits in invertebrate communities still exist (Wong et al., 2019), due to the difficulty of identifying and measuring functional traits, particularly soil fauna (Mori et al., 2015a; Brousseau et al., 2018). Mori et al. (2015b) note that functional diversity of oribatid mites decreased with litter diversity loss, and these results can provide good guidance for restoring biodiversity. But notably, the functional diversity of intensively managed agricultural soil biota is rarely known, indicating our lack of understanding of soil biota diversity (Brousseau et al., 2018).

In this study, we investigated the year-round fluctuation of soil mite communities in apple orchards and aimed to (1) make the community composition of soil mites in orchards at the study site clear and (2) show the temporal pattern of agricultural soil mite communities (taxonomic and functional) among the four seasons.

## Materials and methods

### *Study area*

From June 2021 to May 2022, soil samples were taken once a month in an apple orchard in Pinggu District, Beijing City, China (116.94375°E, 40.21719°N, 124 m a.s.l.). In the orchard, we established five 10 $m^2$ plots, and the plots are spaced 20 m apart from each other. The sampling time covered four seasons: summer (June, July, and August 2021), autumn (September, October, and November 2021), winter (December 2021, January, and February 2022), and spring (March, April, and May 2022). Soil temperature, humidity and pH were also recorded each month in each plot (*Table 1*).

***Table 1.*** *The soil environment (means ± standard deviations) in each sampling month*

| Year | Month | Temperature °C | Humidity % | pH |
|---|---|---|---|---|
| 2021 | June | 24.649 ± 0.094 | 16.757 ± 0.868 | 6.936 ± 0.515 |
| | July | 26.366 ± 0.150 | 27.380 ± 0.903 | 6.516 ± 0.489 |
| | August | 25.401± 0.158 | 27.047 ± 1.022 | 6.503 ± 0.459 |
| | September | 22.002 ± 0.177 | 27.445 ± 1.123 | 6.133 ± 0.482 |
| | October | 14.269 ± 0.204 | 26.863 ± 1.238 | 4.707 ± 0.325 |
| | November | 5.678 ± 0.834 | 23.285 ± 1.757 | 5.567 ± 0.234 |
| | December | 1.215 ± 0.125 | 21.379 ± 1.125 | 5.922 ± 0.373 |
| 2022 | January | -0.217 ± 0.077 | 21.379 ± 1.125 | 5.282 ± 0.783 |
| | February | 0.141 ± 0.089 | 15.601 ± 0.778 | 5.405 ± 0.652 |
| | March | 10.753 ± 0.188 | 20.932 ± 1.575 | 5.975 ± 0.413 |
| | April | 15.725 ± 0.126 | 19.337 ± 1.450 | 6.898 ± 0.653 |
| | May | 19.801 ± 0.058 | 20.465 ± 1.274 | 6.545 ± 0.523 |

Temperature = soil temperature; Humidity = relative humidity of soil; pH = pH of soil

### *Sampling and identification*

In each plot, soil samples were taken with a soil corer (diameter 5 cm, depth 10 cm) to two depths (0 - 10 cm and 10 - 20 cm) and with five replicates, a total 5 plots × 2 different soil depth samples × 12 months = 120 samples (*Fig. 1*). Tullgren-Berlese funnels were used to extract the soil mites, the samples were slowly dried by bulbs (40 W), forcing the mites to move downwards. The extraction period was 48 h with continuous light, and the mites were preserved in 75% ethanol. Specimens were temporarily mounted in lactic acid on cavity slides for identification. All specimens were examined under a transmission light microscope “Leica DM 2500”. All adult mites were identified to species according to Krantz and Walter (2009), Chen et al. (2010), and Subías (2022).

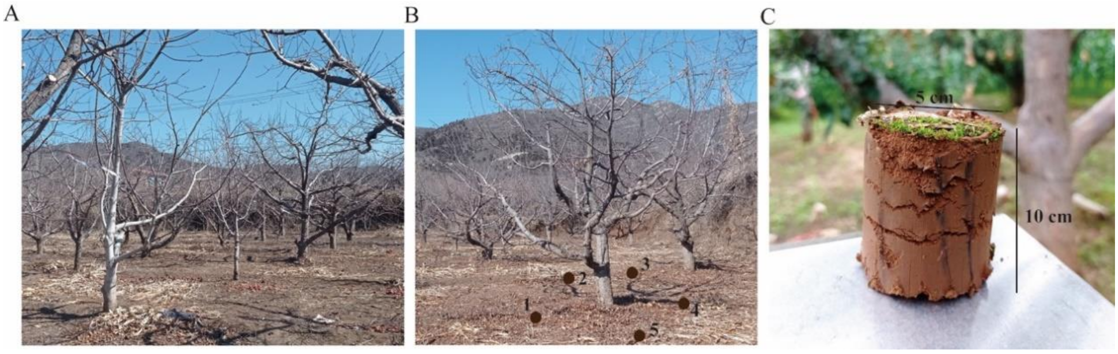

***Figure 1.*** *A) The sampling apple orchard; B) One of the sampling plots; C) The soil core. A and B were taken in February 2022; C was taken in August 2021*

### *Statistical analyses*

All analyses were conducted with R 4.1.0 (http://www.R-project.org). The seasonal fluctuation of soil mite abundance and species richness were obtained by direct count, and the Shannon diversity index ($H'$) was calculated with *Equation 1*, and $N_i$ is the proportion of the abundance of the i mite group to the total mite individual number (Villagomez et al., 2019).

$$H' = -\sum N_i \ln N_i \qquad \text{(Eq.1)}$$

The change in mite groups from each month was calculated to detect the seasonal variability of soil adult mites. These findings were shown in chord diagrams created in R using the 'circlize' (Gu, 2014). Lines connected mite groups and months, and the width of the line shows the mite community seasonal changes. Based on the Bray-Curtis dissimilarity index, nonmetric multidimensional scaling (NMDS) analysis was employed to show the structure of the mite community, and analysis of similarities (ANOSIM) was used to assess the difference of communities (Jiao et al., 2022). The relationship and significance among several taxa of mites and soil factors was tested by a multiple correlation analysis of Pearson (Villagomez et al., 2019).

Considering the importance of oribatid mite in soil faunal composition and soil ecosystem function (Maraun et al., 2007; Ingimarsdottir et al., 2012), the functional diversity and traits of oribatid mite were analyzed used R package ‘FD’. Functional traits can be divided into effect and response traits (Mori et al., 2013). Consequently, based on previous studies on oribatid mite functional traits (Mori et al., 2015a; 2015b), the body size (body length and body width), presence/absence of pteromorphae, number of claws, sensillus types, number of setae were used for the functional diversity analyses. The functional traits of some oribatid mite were measured at least five individuals of each

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species and used mean values to describe species-specific traits, meanwhile, some data were determined to a review of the literature.

Functional diversity of oribatid mite was calculated as the mean pairwise distance in trait values among oribatid mite species, again weighted by oribatid mite abundance, and expressed as Rao's quadratic entropy index, RaoQ (Rao, 1982) and functional evenness index (FEve). RaoQ embraces two components: functional richness and divergence (Mouchet et al., 2010). Functional evenness (FEve) describes the evenness of abundance distribution in a functional trait space and indicates the efficiency of effective resource utilization (Villeger et al., 2008). We further calculated the community-weighted mean (CWM) of each oribatid mite functional trait (Laliberté and Legendre, 2010; Xie et al., 2022). The results in different seasons were evaluated by one-way ANOVA and analyzed with a Tukey HSD test. Non-parametric tests were performed if the data did not meet ANOVA assumptions (the Kruskal-Wallis test was used to compare more than two samples).

## Results

From June 2021 to May 2022, a total of 7238 mites were collected, belonging to 31 families, 37 genera, and 45 species (*Table 2*). There were 4294 adult oribatid mites and 2128 juvenile oribatid mites (23 families, 27 genera, and 29 species); 306 adult mesostigmat mites and 510 juvenile mesostigmat mites (8 families, 10 genera, and 16 species). The five most abundant species throughout the study were *Scheloribates latipes* (1614 individuals), *Oribatula truncate* (967 individuals), *Ramusella sengbuschi* (481 individuals), *Scheloribates fimbriatus javensis* (394 individuals), and *Tectoribates mahunkai* (385 individuals), which represented 83.5% of the total adult mites.

In the apple orchard, monthly abundances of all adult and juvenile mites fluctuated. The highest abundance was recorded in June 2021, while the lowest was presented in April 2022 (*Table 3*). In June 2021, there was the highest abundance of juvenile mites, and the lowest appeared in September 2021. However, the lowest richness was also recorded in June 2021, and there were two species with the greatest abundance: *Oribatula truncata* (619 individuals) and *Scheloribates latipes* (290 individuals). The trends of adult mite and juvenile mite abundances were generally consistent. Among the four seasons, one-way ANOVA results showed that there was no significant difference ($p > 0.05$) among abundance (adults and juveniles), species richness, and Shannon diversity index of mites. Similarly, seasonal variation of adult mite abundance was not significant ($p = 0.076$), but the abundance of mites in the summer is significantly higher than that in the autumn ($p = 0.038$) and winter ($p = 0.009$).

The relative abundance of adult mites was higher than that of juveniles in spring, summer, and autumn; however, the relative abundance of juveniles (59.7%) was higher than that of adults (41.3%) in winter (*Fig. 2A*). In different soil depths, the abundance of upper (0 - 10 cm) mites was higher than that of lower (10 - 20 cm) mites among the four seasons, but the relative abundance of two soil layer mites was similar in the winter (*Fig. 2A*). NMDS ordination plots revealed separate clustering of adult mite community composition across seasons (*Fig. 2B*). Analysis of similarities (ANOSIM) showed that the mite community composition was significantly different among four seasons ($p = 0.001$).

***Table 2.*** *Total abundances (Ind) of mites among four seasons*

| Taxon | Spring (Ind) | Summer (Ind) | Autumn (Ind) | Winter (Ind) | Total (Ind) |
|---|---|---|---|---|---|
| **Mesostigmata** | 96 | 154 | 29 | 27 | 306 |
| *Gaeolaelaps aculeiferoides* (Teng,1982) | 4 | 74 | 2 | 1 | 81 |
| *Gaeolaelaps queenslandica* (Womersley, 1956) | - | 2 | 5 | - | 7 |
| *Gaeolaelaps* sp. | - | - | 1 | - | 1 |
| *Gamasiphis novipulchellus* (Ma et Yin,1998) | 2 | 6 | 1 | 4 | 13 |
| *Gamasiphis* sp. | 2 | 1 | - | - | 3 |
| *Laelaspis digitalis* (Teng,1982) | - | 4 | - | - | 4 |
| *Lasioseius sugawari* (Ehara,1964) | 1 | - | - | - | 1 |
| *Macrocheles* sp. | 5 | 1 | 2 | - | 8 |
| *Neparholaspis* sp. | - | - | 1 | - | 1 |
| *Pachyseius* sp. | - | - | - | 2 | 2 |
| *Parasitus beta* (Oudemans et Voigts,1904) | 25 | - | 6 | 13 | 44 |
| *Parasitus consanguineus* (Oudemans et Voigts,1904) | 2 | 63 | 1 | - | 66 |
| *Parasitus* sp. | - | 1 | - | 1 | 2 |
| *Parholaspulus* sp. | 4 | - | 1 | - | 5 |
| Uropodidae sp. 1 | 19 | 1 | 8 | 1 | 29 |
| Uropodidae sp. 2 | 32 | 1 | 1 | 5 | 39 |
| **Oribatida** | 1131 | 1551 | 1065 | 547 | 4294 |
| *Acrotritia sinensis* (Jacot, 1923) | - | 11 | 9 | 4 | 24 |
| *Berlesezetes ornatissimus appalachicola* (Jacot, 1938) | 4 | - | - | 2 | 6 |
| *Dimidiogalumna* sp. | - | 3 | - | - | 3 |
| *Epilohmannia minuta pacifica* (Aoki, 1965) | 13 | 10 | 27 | 8 | 58 |
| *Epilohmannia* sp. | 2 | 1 | 4 | 3 | 10 |
| *Eremobelba* sp. | - | 1 | - | - | 1 |
| *Eremulus* sp. | 1 | - | - | - | 1 |
| *Fosseremus sculpturatus* (Mahunka, 1982) | 11 | - | - | 2 | 13 |
| Galumnidae sp. | - | - | - | 1 | 1 |
| *Hoplophorella cucullata* (Ewing, 1909) | 7 | - | 1 | - | 8 |
| *Hypochthonius luteus* (Oudemans, 1917) | 6 | 4 | - | - | 10 |
| *Lauroppia* sp. | 57 | - | - | 10 | 67 |
| *Masthermannia* sp. | 7 | 3 | - | 7 | 17 |
| *Nothrus borussicus* (Sellnick, 1928) | 5 | - | 1 | 1 | 7 |
| *Oribatula* sp. | - | 8 | - | - | 8 |
| *Oribatula truncata* (Aoki, 1961) | 342 | 625 | - | - | 967 |
| *Papillacarus echinatus* (Li et Chen, 1991) | 6 | 5 | 1 | 3 | 15 |
| Parakalummidae sp. | - | - | - | 1 | 1 |
| *Peloribates angulatus* (Bayartogtokh, 2000) | - | - | - | 1 | 1 |
| *Protoribates capucinus* (Berlese, 1908) | 5 | 1 | 6 | 5 | 17 |

| Taxon | Spring (Ind) | Summer (Ind) | Autumn (Ind) | Winter (Ind) | Total (Ind) |
|---|---|---|---|---|---|
| *Ramusella sengbuschi* (Hammer, 1968) | 114 | 107 | 117 | 143 | 481 |
| *Scheloribates fimbriatus javensis* (Willmann, 1932) | 132 | 99 | 62 | 101 | 394 |
| *Scheloribates latipes* (Koch,1844) | 279 | 502 | 712 | 121 | 1614 |
| *Scutovertex glandulosus* (Balogh et Mahunka, 1965) | - | 2 | - | - | 2 |
| *Suctobelbella elegantula* (Hammer, 1958) | 5 | - | - | 4 | 9 |
| *Tectocepheus velatus* (Michael, 1880) | 44 | 10 | 39 | 40 | 133 |
| *Tectoribates mahunkai* (Aoki, 1974) | 78 | 159 | 75 | 73 | 385 |
| *Triautogneta higoensis* (Fujikawa, 2009) | 4 | - | - | 3 | 7 |
| *Triautogneta masahitoi* (Aoki, 1963) | 9 | - | 11 | 14 | 34 |

***Table 3.*** *Monthly numerical attributes of soil mite communities*

| Year | Month | A | J | MA | MJ | Richness | Shannon diversity |
|---|---|---|---|---|---|---|---|
| 2021 | June | **1147** | **575** | **229.4 ± 204.1** | **115.0 ± 114.9** | *14* | 2.012 |
|  | July | 168 | 212 | 33.6 ± 14.6 | 42.4 ± 32.2 | 19 | 3.045 |
|  | August | 390 | 85 | 78.0 ± 77.5 | 17.0 ± 8.2 | 17 | 2.239 |
|  | September | 559 | *47* | 111.8 ± 108.8 | *9.4 ± 4.3* | *14* | *1.163* |
|  | October | 295 | 62 | 59.0 ± 54.7 | 12.4 ± 6.0 | 16 | 2.023 |
|  | November | 240 | 199 | 48.0 ± 43.9 | 39.8 ± 35.8 | 15 | 2.816 |
|  | December | 325 | 487 | 65.0 ± 37.8 | 97.4 ± 97.3 | 22 | 2.965 |
| 2022 | January | 100 | 189 | 20.0 ± 4.2 | 37.8 ± 18.9 | *14* | 2.891 |
|  | February | 149 | 176 | 29.8 ± 18.0 | 35.2 ± 18.3 | 18 | 3.224 |
|  | March | 448 | 359 | 89.6 ± 43.9 | 71.8 ± 102.4 | **25** | **3.485** |
|  | April | *47* | 78 | *9.4 ± 9.3* | 15.6 ± 15.4 | *14* | 3.203 |
|  | May | 732 | 169 | 146.4 ± 63.0 | 33.8 ± 12.3 | 22 | 2.415 |

Maximum values of each parameter are in bold, and the minimum values of each parameter are in italic. A = the number of adult mites; J = the number of juvenile mites; Richness = number of species; MA = means of the number of adult mites ± standard deviations; MJ = means of the number of juvenile mites ± standard deviations

The chord diagram shows the composition of mite community clearly in each month and each season (*Fig. 3*). In the orchard, oribatid mites accounted for a higher proportion than mesostigmat mites, and Scheloribatidae showed a high relative abundance and appeared in each month. The low abundance groups just appeared in certain months or seasons. Meanwhile, the Oribatulidae only appeared in May and June and occupied a large abundance. The dominant taxa of oribatid and mesostigmat mites varied in different seasons. For oribatid mites, Scheloribatidae with the highest abundance in spring (411 individuals), autumn (774 individuals), and winter (222 individuals); Oribatulidae with the highest abundance (633 individuals) in summer. For mesostigmat mites, Uropodidae with the highest abundance in spring (51 individuals) and autumn (9 individuals); Parasitidae with the highest abundance in summer (64 individuals) and winter (14 individuals).

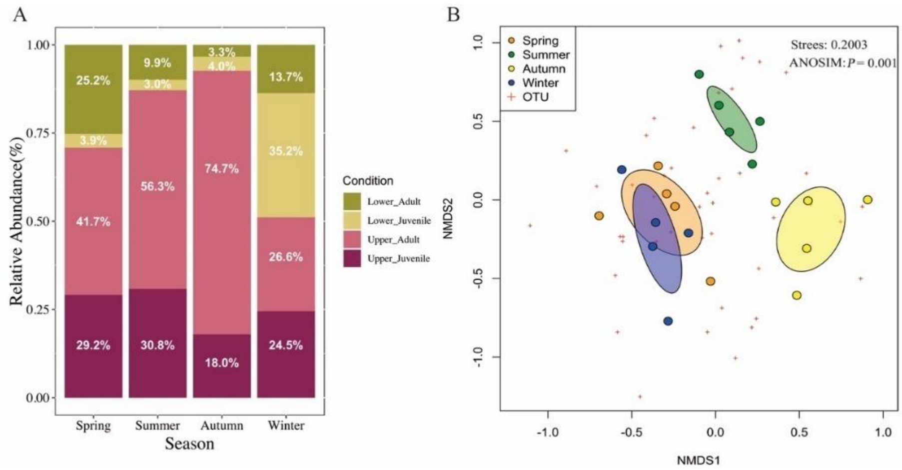

**Figure 2.** *A) The relative abundance of mites at different soil depths among four seasons; B) Nonmetric multidimensional scaling (NMDS) analysis showing mites community structure in different soil depths. Ellipses refer to the standard deviation around the centroids of each soil depth, red crosses represent the parasite OTUs in each community. Analysis of similarities (ANOSIM) statistic R = 0.536. Lower_Adult = the adult mites in 10 - 20 cm soil layer; Lower_Juvenile = the juvenile mites in 10 - 20 cm; Upper_Adult = the adult mites in 0 - 10 cm soil layer; Upper_Juvenil = the juvenile in 0 - 10 cm soil layer*

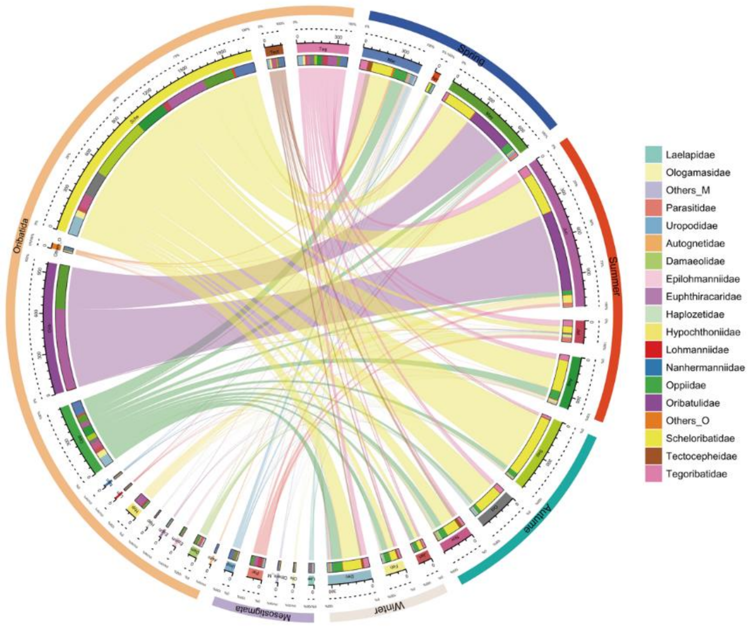

**Figure 3.** *The adult mite chord diagram. from the outside circle to the inside. The left side of the first circle is the names of Oribatida and Mesostigmata; the length indicates the proportion of the abundance of mites. The right side of the first circle represents the four seasons. The second circle is a percentage scale label (from 0 - 100%). The third circle is the family name and month, and the width of the line indicates the abundance of mites. The left side of the fourth circle indicates which group appeared in which month, different colors represent different months, and the right side of the fourth circle indicates which group appeared in this month; different colors represent different mite groups. Mites and months connect with lines; the width of the line indicates the abundance of mites. We grouped the oribatid mites with single-digit abundance as others_O and the mesostigmat mites as others_M*

For the Pearson's correlations between edaphic factors and the abundance of the top ten families of mites, the relationship between temperature and Laelapidae (r = 0.41), Parasitidae (r = 0.32), Oribatulidae (r = 0.31), and Tectocepheidae (r = -0.29); and the relationship between pH and Laelapidae (r = 0.33) and Oribatulidae (r = 0.26) was significant. However, the correlations indicated only a very weak connection between the variables. In addition, there were also marked relationships among several taxa, and soil humidity did not have a significant interaction with these taxa of mites (*Fig. 4*).

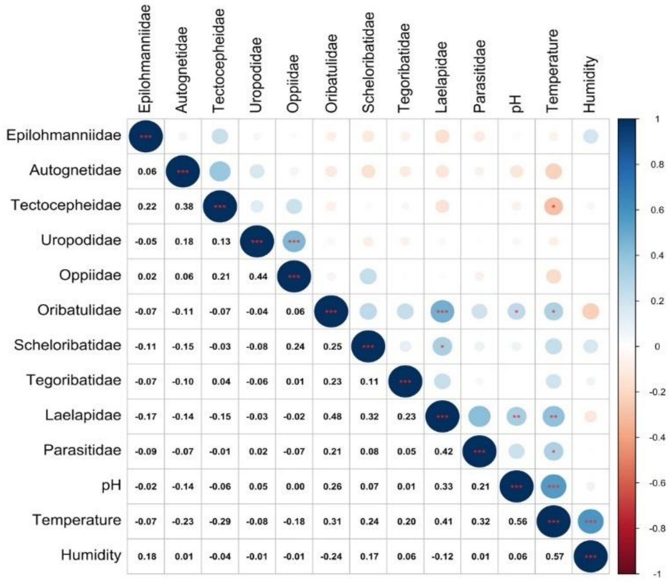

***Figure 4.** Pearson correlation of several taxa of mites and soil abiotic factors. *Significance level: * p < 0.05, ** p < 0.01, *** p < 0.001*

Kruskal-Wallis test showed a significant relation between collecting seasons with functional evenness index (FEve) of oribatid mites (p = 0.023), and the relation with functional diversity (RaoQ) was not significative (p = 0.367). The functional evenness index (FEve) in winter was significantly higher than it in spring and summer (*Fig. 5A*). The community-weighted mean (CWM) body length (p = 0.019) and body width (p = 0.048) of oribatid mites were significantly different among four seasons (*Fig. 5BC*). There was the highest body size (body length and body width) of oribatid mites in autumn.

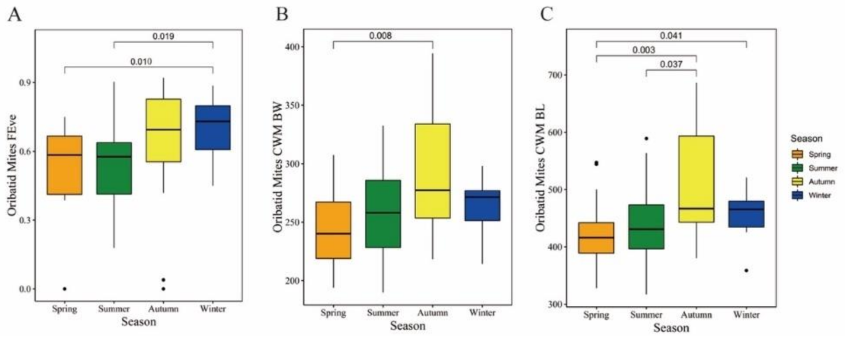

***Figure 5.** A) Oribatid mites functional evenness index (FEve) in different seasons; B) Community-weighted mean (CWM) body width of oribatid mites in different seasons; C) Community-weighted mean (CWM) body length of oribatid mites in different seasons*

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## Discussion

In most habitats, mites account for an important part of soil microarthropods because of their large abundance and species richness (Amani et al., 2020). However, in the orchards we studied, *Scheloribates latipes, Oribatula truncate, Ramusella sengbuschi, Scheloribates fimbriatus javensis*, and *Tectoribates mahunkai* as the five most abundant species throughout the study, represented 83.5% of the total adult mites (*Table 1*). Due to agricultural activities (soil tillage, mineral fertilization, and crop diversity reduction), soil biological diversity at different levels within the soil food web has been affected (Behan-Pelletier, 2003; van Diepeningen et al., 2006). Because of the small body size and limited dispersal ability, soil mite community fluctuation results mainly response to local environment factors, resulting in the survival of those species that are suited to their environment and the extinction of others (Corral-Hernández et al., 2016; Wehner et al., 2018).

Our results showed the highest abundance in June 2021, while the lowest in April 2022 (*Table 3*). Moreover, there was no significant difference in abundance, species richness and Shannon index of mites among four seasons. The community structure of the mites varied among the four seasons (*Fig. 2*), and the dominant taxa of oribatid and mesostigmat mites varied in different seasons (*Fig. 3*). Ecologically, the community structure of mites depends on the seasonality of soil environment (temperature and humidity) (Wehner et al., 2018; Xin et al., 2018). However, in our investigation, soil temperature and pH had substantial effects on major mite taxa, while humidity was not significant (*Fig. 4*).

Furthermore, the community variations of mites also depend on intra-community parameters, such as the biology of the studied groups. On the one hand, Stamou et al. (2004) highlighted the importance of adult mite fecundity, which they considered an essential part of maintaining community abundance. On the other hand, mesostigmat mites of almost all species are predators, and their community fluctuations are similar to those of their prey, including nematodes, springtails, and other mites (Wissuwa et al., 2012; Fujii and Takeda, 2017; Bolger et al., 2018). Significant correlations were found in the current study between mesostigmat mites and oribatid mites (*Fig. 4*), these relationships may be employed to explain the possible trophic interactions within the mite communities (Seniczak et al., 2018).

Mite community functional diversity was reported to be influenced by agricultural management and resource porting, playing an important role in the provisioning of ecosystem services (Flynn et al., 2009; Karp et al., 2012). In this study, we focused on the functional diversity (RaoQ and FEve) and functional traits of oribatid mites and found that there was a difference among the four seasons. For body size, it was considered a constraint on resource consumption and delivery in soil food webs (Andriuzzi et al., 2020; Bluhm et al., 2021). In our study, the body size of mites in autumn and winter was larger than that in spring and summer, and higher efficiency of available resource utilization was observed in autumn and winter (*Fig. 5*). In contrast, when resources are scarce, body size is disproportionately small (Mulder et al., 2011). Unfortunately, there was no resource data recorded during the sampling period, and the research on resources and mite body size was not conducted.

In addition, environmental variables such as moisture and temperature influenced the functional structure of the soil ecosystem (Ferris et al., 2001). Humidity is a primary driver of production in terrestrial ecosystems and an essential regulator of resource availability (Knapp et al., 2008, 2017), and it may supply mites with a large resource to overcome the limiting constraint of body size. On the other hand, the abundance of mites in spring and summer was higher than that in autumn and winter, and there was a negative relationship between community body size and abundance, which has important implications for energy usage and resource partitioning (Woodward et al., 2005; White et al., 2007). Because of the negative relationship between community body size and abundance, the studied orchard soil body size of oribatid mites in spring and summer is generally smaller than that in autumn and winter (*Fig. 5*).

## Conclusion

We accomplished the initial goal of our study and gained a better knowledge of the seasonal changes of soil mite community in the apple orchards of China. The results of this study provide background information for the study of soil mites in apple orchards in Beijing, China. The five most abundant species in the orchards represented 83.5% of total adult mites, and the diversity was smaller compared to temperate forest ecosystems. The abundance, species richness, and Shannon index of mites were similar among the four seasons, but the mite community structure was different in the four seasons. The reasons for this result are complicated, and it might be the consequence of a combination of seasonal fluctuations in soil environment and agricultural productivity, which need more research to confirm. Above-ground and below-ground interactions exist in orchards, and research into the functional diversity and functional traits of soil mites can help us comprehend these interactions. However, the lack of data on mite feeding habits and food sources leading to our lack of knowledge about the apple orchard soil food web. Future research should focus on determining which factors influence the composition and diversity of agricultural soil mites, and to what extent.

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